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Thermal Insulation With Reflective Surfaces

BUILDING MATERIALS RESEARCH at the National Bureau of Standards has shown that air spaces in buildings give much better insulation if they are surfaced on one side, or subdivided, with highly reflective surfaces such as aluminum foil.[1] Moreover, the use of reflective surfaces on typical fibrous insulating materials of blanket, batt, or board form installed with adjoining air spaces increases materially their insulating effect, especially where the direction of heat flow is downward. The investigation was carried out in cooperation with the Aluminum Company of America by H. E. Robinson and F. J. Powell of the Bureau's heat transfer laboratory and L. A. Cosgrove of Alcoa's Research Fellowship at the Bureau. The resulting data should be of interest to manufacturers of insulating materials and to architects, engineers, and builders concerned with thermal insulation.

NBS research in 1954 made available a method and the essential data for calculating the thermal conductance of air spaces of uniform thickness (i. e., air spaces of an exemplary type) under various environmental conditions.[2] These measurements showed that reflective surfaces increase the insulating values of air spaces to a large extent. Therefore, it appeared reasonable to assume that the substantial thermal resistance of fibrous insulating products could similarly be augmented with highly reflective surfaces. However, it was not known how much the insulating value of an air space formed in combination with a reflectively surfaced fibrous insulation might depart from that of the exemplary type of space as a result of the circumstances of the application. The Bureau therefore undertook to ascertain experimentally the insulating effects of a number of reflective and fibrous materials installed in different combinations, and to compare the results with calculated values based on the previously obtained data.

The heat-transfer measurements were performed on test panels in the Bureau's rotatable guarded hot box apparatus. The apparatus consists essentially of two chambers coupled together to form two well-insulated enclosures, with the test panel interposed between them. One enclosure is electrically heated; the other is refrigerated. They are maintained steadily at typical warm-side and cold-side temperatures—70° and 0° F, respectively. A third enclosure, or metering box, is placed against the central area of the warm side of the test panel, and is kept at the same temperature as the warm enclosure. Under this condition, there is little exchange of heat between the metering box and the surrounding enclosure. The accurately measured electric-power input to the metering box indicates the rate of heat flow through a known area of the test panel under the test conditions. Since the insulating effect of an air space is markedly affected by its orientation, the entire apparatus can be rotated on a horizontal axis to test a panel in positions simulating its use as a floor, wall, or ceiling. The apparatus is designed to handle

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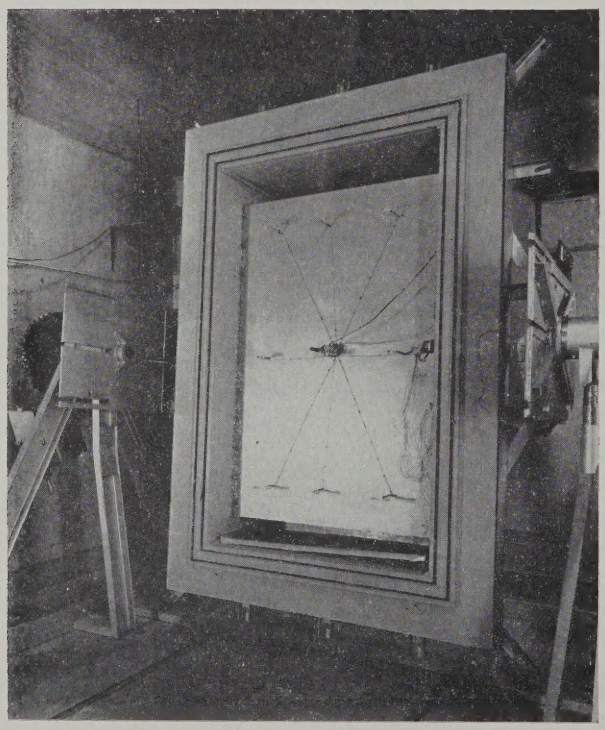
panels 5½ by 8 ft in size, and conforms substantially to ASTM requirements.[3]

The series of tests included 28 test panels, 23 of which were insulated with reflective membranes used alone or in combination with fibrous insulations. The remaining panels were for comparative measurements on insulations without reflective surfaces. The panels were tested at five different orientations, progressing by 45° angles from horizontal with heat flow downward to horizontal with heat flow upward. Part of the investigation covered tandem air spaces, i. e., two spaces in series separated by a reflective membrane. This part was concerned with the effects on insulating value of moisture condensation on reflective surfaces, air circulation between the spaces through holes in the membrane, minute perforations in the membrane intended to make it vapor-permeable, and nonuniform thickness (wedge shape) of the air spaces. The remainder of the investigation was devoted to measurements on panels containing commercial types of fibrous insulation with surfaces of various reflectances.

Major findings of the investigation are summarized below:

1. Observed insulating values for panels were in agreement with calculated values within 10 percent or better in almost all cases where the air-space conditions conformed to those of the exemplary spaces with which the original data were obtained. Significantly wider departures of observed from calculated values for panels were observed as a result of such factors as condensation of moisture on reflective surfaces, lack of uniformity of air-space thickness, air circulation between tandem air spaces, and effects attributed to local high conductance at edges of insulating blankets or radiation from framing members.



Guarded hot box open to show test panel in place. Thermocouples are attached to numerous points on the surface of the panel for temperature measurements.

2. Condensation of moisture on reflective surfaces decreased the insulating effect of an air space. The observed decrease ranged from 30 percent for a horizontal air space with heat flow downward to 10 percent for other orientations. Condensation on a reflective membrane used in a critical position can be avoided by making the membrane adequately vapor-permeable.

3. The insulating effect of tandem wedge-shaped air spaces was materially less than that of air spaces uniformly of the same average thickness. For tandem wedge-shaped spaces formed by aluminum foil stretched diagonally from the front to back faces of adjacent 2- by 4-in. studs on 16-in. centers, the observed thermal resistances were 53, 75, and 78 percent of those calculated for tandem uniformly thick spaces formed by a foil membrane midway between the panel faces, for heat flow downward, horizontal, and upward, respectively.

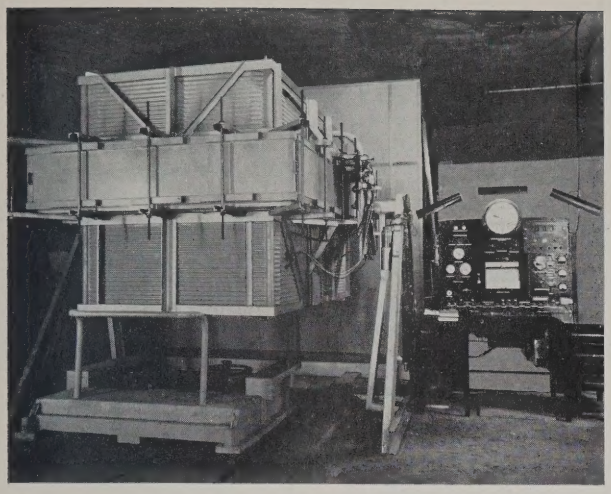
4. Circulation of air between tandem air spaces through three holes near each end of the dividing aluminum-foil membrane caused reductions of 18 and 12 percent in the insulating effect of the air spaces when they were vertical or at a 45° angle, respectively. The holes were 0.58 in. square, and at each end totalled 1 in.^{2} in area in a membrane 30 in. wide. No significant loss of insulating effect was observed when the air spaces were horizontal.

5. It was shown analytically that minute perforations in a highly reflective aluminum foil membrane dividing two tandem air spaces decrease the insulating effect of the membrane as a result of radiation through the apertures. The reduction in air-space thermal resistance caused by the perforations depended on panel orientation and direction of heat flow. The reduction ranged from about 20 percent for heat flow downward to about 5 percent for heat flow upward, where the membrane had 64 perforations per square inch totaling 1.6 percent of the area. Air circulation through the perforations described had no appreciable effect on the insulating value of the two adjoining air spaces in any orientation.

6. Tests of tandem air spaces, 3.8 in. thick and 14.4 in. wide, indicated that the thermal resistance of a thick air space with one reflective surface may depend to some extent on the position of that surface because of effects due to radiation from the sides of the framing.

7. When observed and calculated resistances were compared for panels insulated with a board-type fibrous insulation of uniform thickness, without and with reflective surfaces on the board, the values agreed within 7 percent or better. Observed resistances for individual air spaces agreed within 6 percent in 13 of the 15 cases in which aluminum foil was applied to the board insulation.

8. For 7⅝-in. panels insulated with 2-in. mineral-wool aluminum-foil-enclosed blanket insulation in approximate midspace, observed resistances were within about 10 percent of the calculated values, except for cases of heat flow downward. Here, departures of



The rotatable guarded hot box apparatus (left) used in thermal insulation studies. In this horizontal position, heat transfer measurements can be made on thermal insulating materials where heat flow is downward. At right is the control console.

about 20 percent were found. Observed resistances for individual air spaces were in a few extreme cases as much as 30 percent lower than calculated values. In these cases, the departures were attributed chiefly to the effects of nonuniform thickness and conductance of the installed blanket. The reduction of thickness and conductance of the blanket was especially great at the flanks near framing members. For the four samples of nominal 2-in. blanket insulation used, observed resistances differed by about 40 percent.

9. Tests with four different applications of a 1¼-in low-density mineral-wool blanket with aluminum foil on the warmer side showed that applications with the blanket in midspace of the panel, or bowed into the space from the warm side, were materially more effective than those in which it was stretched tautly over the warm or cold faces of the framing members.

[1] Thermal resistance of air spaces and fibrous insulations bounded by reflective surfaces, *by H. E. Robinson, L. A. Cosgrove, and F. J. Powell, Building Materials and Structures Report 151, available from Superintendent of Documents, Government Printing Office, Washington 25, D. C. (20c).*

[2] The thermal insulating value of airspaces, *Housing Research Paper 32, available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. (25c).*

[3] Method of test for thermal conductance and transmittance of builtup sections by means of the guarded hot box, *ASTM C236–54T.*

Radio Scientists Attend URSI Conference

MEETING in the United States for the first time since 1927, the International Scientific Radio Union (URSI) held its 12th general assembly in Boulder, Colorado, from August 22 through September 5, under the chairmanship of the Rev. P. Lejay, S. J.; Dr. L. V. Berkner of Associated Universities, Inc., N. Y., was elected the new international president of the Union.[1] More than 500 delegates from 26 countries responded to the invitation of the U. S. A. National Committee of URSI and the National Academy of Sciences. The scientists met to exchange technical information, coordinate international research efforts, and recommend future projects.

Local hosts were the Boulder Laboratories of the National Bureau of Standards, the University of Colorado, the High Altitude Observatory, and the City of Boulder. Dr. J. Howard Dellinger, formerly Chief of the NBS Central Radio Propagation Laboratory and now a consultant in Washington, D. C., was chairman of general arrangements. K. A. Norton, Chief of the radio propagation engineering laboratory, and A. H. Shapley, Chief of the sun-earth relationships section of the radio propagation physics laboratory, both of the NBS Boulder Laboratories, were in charge of local arrangements.

URSI (named from the initials of its French title, Union Radio Scientifique Internationale) was founded in 1919 as a medium for worldwide cooperation in radio research. Besides fostering scientific discussion and exchange of ideas at the general assemblies which meet every 2 or 3 years, URSI is organized into 7 permanent commissions that are continuously active on a national and international basis. The areas assigned to these commissions and the international chairmen are, respectively: I Radio Measurement Methods and Standards, Dr. B. Decaux (France); II Tropospheric Radio Propagation, Dr. R. L. Smith-Rose (England); III Ionospheric Radio Propagation, Dr. D. F. Martyn (Australia); IV Radio Noise of Terrestrial Origin, J. A. Ratcliffe (England); V Radio Astronomy, Dr. M. Laffineur (France); VI Radio Waves and Circuits, Prof. S. Silver (U. S. A.); and VII Radio Electronics, Prof. G. A. Woonton (Canada). The papers and discussions of the general assembly were also organized around these major fields of activity.

I. Radio Measurements and Standards

Much of the discussion on radio measurements and standards dealt with standards of time and frequency. Dr. L. Essen (National Physical Laboratory, Teddington, England) surveyed recent improvements in quartz-crystal oscillators and the development of atomic frequency standards such as the ammonia MASER and the cesium-beam standard; he also described a cesium standard which has been used as a reference since 1955.

W. D. George (NBS) summarized developments in standard frequency transmission and time signals. The

problem of interference among the 14 broadcasting stations doing such work in various parts of the world was discussed, and a resolution was adopted containing several proposals for relieving the situation. The use of VLF to reduce propagation errors was another topic of discussion.

Among the U. S. A. papers were accounts of experiments with oxygen as an atomic frequency standard, development work on the microcalorimeter, phase stabilization of klystrons, the standardization of r-f quantities, and the distinction between field intensity and field strength.

Dr. J. A. Saxton (D. S. I. R. Radio Research Station, Sloush, England) reported on numerous developments in r-f power measurements during the last 3 years. Discussions of the measurements of r-f fields, including definition of field strength and field intensity, were led by R. S. Kirby (NBS) and Prof. P. Givet (University of Paris, France).

A resolution was adopted recommending international intercomparison of atomic frequency standards. The resolution of an earlier meeting calling for intercomparison of microwave power standards was reaffirmed; it was noted that such intercomparison is now under way with the submission by Japan of a calibrated bolometer mount to the Bureau's radio standards laboratory.

Members of Commission IV, Radio Noise of Terrestrial Origin, and Commission V, Radio Astronomy, gather together before their tour of the Boulder Laboratories.

II. Tropospheric Radio Propagation

The first few sessions on the propagation of radio waves through the troposphere were devoted to within-the-horizon propagation over irregular terrain and to obstacle-gain effects in beyond-the-horizon propagation of VHF and UHF waves. Special attention was also given to both theory and observations on turbulent scattering (forward scatter).

A paper prepared by the Swedish Research Institute of National Defense discussed propagation of 20- to 80-Mc waves over a mixed earth-water path. It showed that, in general, a maximum height gain of roughly 7 db above that expected over a smooth earth is obtained just before reaching the top of a hill, going from land to water; and that, for fresh water, recovery of overwater field strength occurs at 25 to 30 wavelengths from the shoreline. Dr. J. A. Saxton (England) noted that, on the average, within-the-horizon field strengths fall below the smooth earth field at higher and higher frequencies, possibly because antennas intervisible over a smooth earth are not intervisible over actual terrain.

Major contributions to the technical sessions were in two fields: (1) the correlation of radio and meteorological parameters, and (2) extra-diffraction propagation. On the latter, there were lively discussions of competing theories; it appears that the structure of the atmosphere is still not well enough understood to permit a decisive evaluation of the assumptions underlying the various theories.

III. Ionospheric Radio Propation

Papers and discussions on ionospheric propagation formed part of an all-day meeting on the International Geophysical Year. Dr. M. Nicolet (Department of Radiation, Belgium) presented a theoretical discussion of the physical processes of the lower ionosphere from the point of view of neutral particles. Then, turning to experiment, a report was made of Australian observations of ionospheric reflection of 1.75-Mc signals from heights between 54 and 100 km; these were supplemented by the results of observers in Germany and the United States.

Dr. R. A. Helliwell (Stanford University) reported that manmade radio signals had, for the first time, been successfully transmitted along whistler paths from the Northern to the Southern Hemisphere. It is believed that this type of propagation will give important information about the atmosphere far above the ionosphere and may provide a new, and perhaps very reliable, means of long-distance communication.

A comprehensive survey of recent rocket findings was given by Dr. H. Friedman (Naval Research Laboratory); and Dr. J. C. Seddon (NRL) described early results from the first rockets fired in the auroral zone (Ft. Churchill, Canada). The results indicate that at these latitudes, electron densities in the lower ionosphere are considerably greater than at White Sands, N. M.

IV. Radio Noise of Terrestrial Origin

The scientists concerned with terrestrial radio noise agreed that valuable information about the ionosphere can be obtained by comparing the waveforms of the same disturbance (an "atmospheric" or "sferic") due to a lightning discharge as recorded at different ranges from the original discharge. This approach appears more fruitful than earlier work based on differences in waveform types.

Thus, workers at the NBS Boulder Laboratories described a method of calculating the reflection coefficient

of the ionosphere based on waveforms of sferics. Also reported were the IGY arrangements to facilitate the simultaneous recording of waveforms at several stations in Europe. These are in addition to other noise-recording stations throughout the world which are expected to help in solving the more general problems of radio communication as well as in the study of propagation.

Further details on whistlers [2] were reported. It was noted that very few atmospherics give rise to audible whistlers, suggesting that the lightning discharges that do succeed in producing whistlers possess special characteristics. One set of observations indicates that the initiating sferics have a large amount of energy near 5 kc.

Also discussed were measurements on noise from 15 kc to 20 Mc originating largely in lightning discharges. There is now general agreement on which noise characteristics should be measured; and significant progress has recently been made in the description and measurement of amplitude characteristics.

V. Radio Astronomy

The quantity and content of papers on radio astronomy confirmed the rapid expansion of research in this area. Three principal topics were discussed: Techniques of reception, large aerials, and observations of moon, planets, and comets.

Dr. W. N. Christiansen (Commonwealth Scientific and Industrial Research Organization, Australia) described a new "Mills Cross" interferometer operating at 1,420 Mc and capable of producing a complete picture of the radio sun by television-wise scanning with its narrow pencil beam. Dr. A. Hewish (Cavendish Laboratory, Cambridge, England) spoke on the technique of "aperture synthesis," in which an electronic computer replaces a large portion of the array of aerials usually required for observing discrete radio sources.

An impressive number and variety of large aerials were reported as now in use, in construction, or in the planning stage. Professor A. C. B. Lovell (Jodrell Bank Experimental Station, England) described the construction of and first results obtained with the mammoth 250-ft paraboloid at Manchester, England.

J. H. Trexler (NRL) reported moon-echo experiments with a 220-ft parabola which show that the echoes are reflected almost entirely from a relatively small area of the moon's surface; this was confirmed by British work. Using moon-echo methods, B. S. Yaplee (NRL) has measured the distance to the moon so accurately that the principal errors depend on the uncertainties in the earth's radius and the electron density between earth and moon.

VI. Radio Waves and Circuits

Electromagnetic surface waves (i. e., waves trapped at the interface of 2 media) and the related Sommerfeld problem were the main subjects in the area of radio waves and circuits. Dr. H. E. Barlow (University College, London, England) presented a survey of recent ideas on the theory of surface waves and showed that many of their features can be explained by simple physical arguments. Remarks on the mathematics of this controversial subject were also made by Dr. B. van der Pol (Netherlands), Dr. S. A. Schelkunoff (Bell Telephone Laboratories), and N. Markuvitz (Polytechnic Institute of Brooklyn), who made an eloquent plea to bury the Sommerfeld problem once and for all. The consensus was that although the classical cases had been adequately solved, the extension to surface waves with very different features has led to many misconceptions. A committee was formed to prepare a review of the whole subject for the next general assembly.

J. P. Simon (Compagnie Generale de T. S. F., France) disclosed some very recent advances in the design of surface-wave antennas; the principal novelty is that the surface waves are launched on a structure with a modulated phase velocity. An example is the "cigar" antenna—a dielectric rod with concentric metal disks of different sizes. Some mathematical aspects of such tapered surface-wave antennas were considered by F. J. Zucker (Air Force Cambridge Research Center).

VII. Radio Electronics

One of the most interesting sessions of the meeting dealt with the MASER (Microwave Amplification by Stimulated Emission of Radiation) and the entire field of nonequilibrium quantum-mechanical devices to which it belongs. The outstanding advantages of such systems are their extremely low noise figures when used as amplifiers and their extremely high spectral purity as oscillators. The speakers and discussants, led by Professor C. H. Townes (Columbia University), emphasized the considerable variety of possible schemes for obtaining MASER action, from simple two-energy-level beam MASERS to solid state MASERS with 2 or 3 levels that depend on paramagnetic, adiabatic fast passage, and ferromagnetic effects. The availability of low-noise amplifiers was of particular interest to the radio astronomers since they have already reached the limits of sensitivity set by antenna size and observation time.

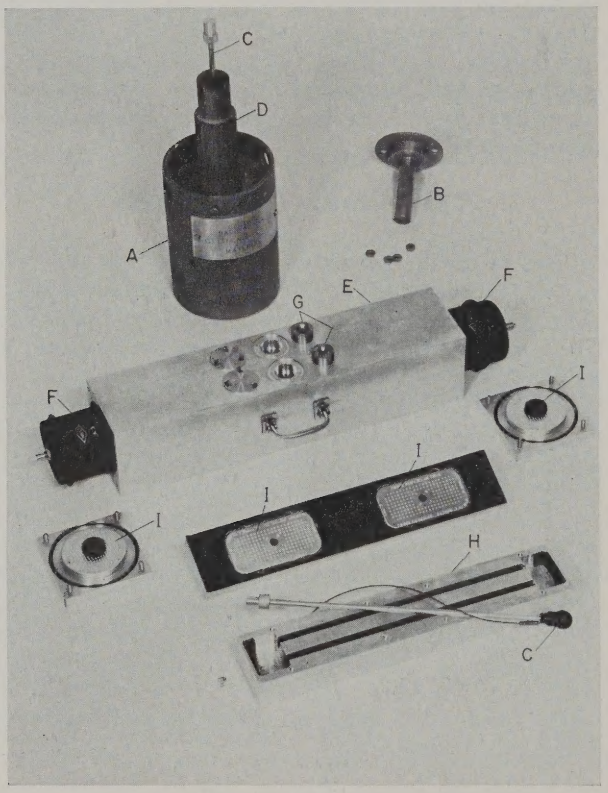
[1] *Because of the great quantity of papers presented and the extent of the discussions at the meeting, the present account mentions only some of the highlights. A full description will be given in the official report which will be published at the URSI headquarters in Belgium.*

[2] *A "whistler" occurs when an electrical disturbance caused by a lightning discharge travels out along the lines of magnetic force of the earth's field until it reaches the magnetically conjugate point on the earth's surface, from which it is then reflected back to the point of origin. Sometimes more than one such "echo" is produced. The characteristic drawn-out descending pitch of the whistler is a dispersion effect due to the greater velocity of the higher-frequency components in the disturbance.*

Portable Standard Radiation-Exposure Instrument

For Intercomparison of National Primary Standards

THE BUREAU has constructed a portable transfer instrument for measurement of radiation exposure dose, as agreed upon at the 1956 meeting of the International Commission on Radiological Units and Measurements (ICRU).[1] Consisting of a small cavity chamber and auxiliary apparatus, the equipment will be available to other countries as an intermediary by which their own primary free-air standards can be compared with that of the United States.[2] It can also be used to measure the gamma radiation from a radioactive source, which could then function as a temporary primary standard, allowance being made for its rate of decay. A set of equipment similar to that prepared for the ICRU has also been constructed for the United Nations Educational, Scientific, and Cultural Organization (UNESCO).



Portable standard instrument and accessories for measuring radiation exposure dose. Prepared at the request of the International Commission on Radiological Units and Measurements (ICRU), the equipment will be used to intercompare the various national free-air primary standards. A is the container of the cesium-137 source with plug, B, removed and a cavity chamber, C, inserted. The hemi-cylinders, D, serve to center the stem of the chamber. Container, E, holds 2 capacitors, F, and 2 diaphragms, G. The 2 cavity chambers are held in container H. Silica gel cannisters, I, reduce humidity in E and H. The cover for A (not shown) contains a length of coaxial cable for connecting C to an electrometer.

Although it is possible to compare the national primary standards with one another directly, this involves a great expenditure of time and effort and is therefore attempted only at infrequent intervals. The purpose of the present portable instrument is to make such comparisons possible on a more frequent basis while maintaining a reasonable level of accuracy.

Use of the transfer instrument is expected to bring about greater uniformity in radiation measurements, so that results obtained in different countries can be more easily and reliably compared. The direct benefits of this should be felt by those engaged in the many activities in which radiation now plays an important part, for example, in the control of therapeutic radiation in hospitals, in fundamental physical studies of radiation, in the applications of radiation to industrial processes, and, of course, in the manufacture of radiation meters.

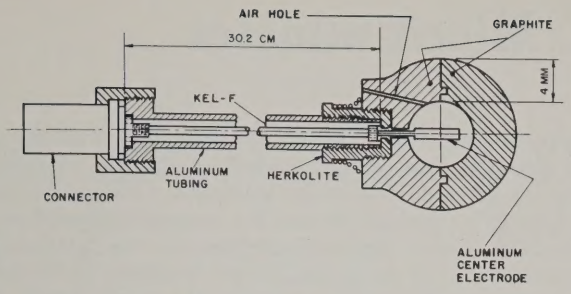
At the 1956 meeting of the ICRU, the Bureau agreed to construct and calibrate a small cavity chamber, a diaphragm for defining accurately the size of the radiation beam, and a charge-compensating capacitor. Since then, it has seemed desirable to increase the number of components. The present kit consists of 2 cavity chambers (in case one develops an electrical leak); a pair of diaphragms with nominal aperture diameters of 1 and 0.7 cm; a pair of capacitors, nominally 100 and 1,000 micromicrofarads; and a cesium-137 radioactive source for checking the constancy of the chambers' sensitivity.

The cavity chambers have been calibrated for radiation in the range from 60 to 250 kev, as well as for gamma radiation from cobalt-60 (a mixture of 1.17- and 1.33-Mev rays). The performance of the instruments is stable to a few tenths of a percent.

Exposure Dose

When gamma- or X-ray photons pass through a material medium, many of them are absorbed and their energy used to eject electrons from atoms of the material. In a gas, the ejected electrons produce ions as they collide with the gas molecules and knock other electrons out of them. The number of ions produced per unit of mass of a particular gas depends on the speed (i. e., the energy) of the original electrons; and this in turn depends on the energy of the radiation. If the gas is electrically neutral to begin with, the total charge on the negative ions is equal to the total charge on the positive ions.

This ability of radiation to produce ionization is used in the determination of "exposure dose," which is a



Cross-sectional diagram of the portable standard cavity chamber constructed for intercomparison of national primary (free-air) standards of radiation exposure dose.

measure of the radiation reaching a given point (i. e., small region), based on the amount of ionization that the electrons originating at the point could produce in air. The unit of exposure dose is the *roentgen*. The exposure dose at a point is 1 roentgen when the electrons originating per 0.001293 gram of air (the mass contained in 1 cm^3 at standard temperature and pressure) can produce negative (or positive) ions of 1-esu total charge.

The primary standard of exposure dose, as maintained at the Bureau and other national laboratories, is a "free-air" ionization chamber. In this instrument (omitting refinements of technique), the beam of rays to be measured is allowed to ionize the air between 2 parallel metal plates; and an electrical field between the plates attracts the ions to the plates as fast as they are formed. Then, by measuring the charge on the ions thus collected, the exposure dose in roentgens can be calculated.

Transfer Instrument

The transfer instrument operates on the same basic principle as the free-air chamber. There is a small chamber of about 1 cm^3 in volume containing air, from which the ions produced by radiation are collected and measured. The wall of the air cavity is made of carbon (graphite) and is 4 mm thick to produce electronic equilibrium for cobalt-60 rays. That is, the wall is just thick enough to keep out electrons ejected by the high-energy cobalt rays from air particles outside the instrument or from such things as the lead-collimating slits that channel the rays into a narrow beam; any greater thickness would absorb too much of the radiation itself before it reached the cavity and would thus reduce the instrument's sensitivity.

Projecting into the cavity is an aluminum center electrode, and the ions are collected by applying an electric potential between this electrode and the carbon wall. A special effort was made to assure good electrical insulation between the high- and low-voltage parts of the circuit. This is necessary since even very small leakage currents (which the instrument cannot distinguish from the flow of ions) would produce spurious readings. As an additional precaution against errors of this kind, a short length of coaxial cable and a connector are provided for connecting the chamber to the electrometer that would be used to measure the charge of the ions.

The sensitivity of the instrument can be checked by removing the lead plug from the cesium-137 source that is part of the kit and inserting the chamber into the holder. To insure reproducibility of measurements, the components are so designed that the chamber can always be put into the same position relative to the cesium source.

Past experience in the direct comparison of free-air chambers has shown that sufficient attention has not always been given to the accurate determination of the characteristics of diaphragms and capacitors. The cross-sectional area of the diaphragm opening determines the volume of air that is irradiated; hence any inaccuracy in the value of the cross-sectional area would be immediately reflected in the ionization measurement. The areas of the openings in the diaphragms supplied with the transfer instrument have been measured to an accuracy of better than one-tenth of 1 percent.

The capacitor also plays a critical part in the ionization measurement, since the charge of the ions is determined by balancing it against a charge placed on the capacitor. In calculating the latter charge, the capacitance of the capacitor must be known. The problem here is to eliminate the effects of variable stray capacitance. This is done by enclosing the capacitor in a metal shield so that the stray capacitance becomes fixed and is no longer affected by conducting objects in the vicinity of the instrument.

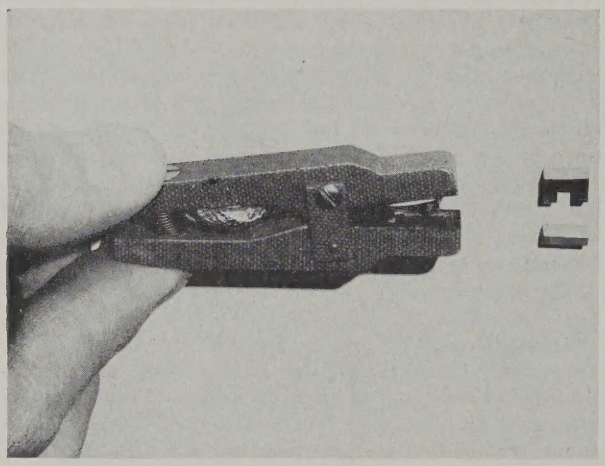
The transfer instrument differs from the primary free-air standard in that the ions collected from the air are partly due to electrons ejected from carbon atoms in the cavity wall. As a result, the relationship between the ionization charge and the exposure dose is less direct than in the primary standard. However, for the purposes of a transfer instrument it is only required that the readings be stable and reproducible; and the present instrument has been designed to fulfill these conditions. This being the case, it is possible to compare the primary standards with one another by noting how each compares in turn with the transfer instrument.

[1] *See pages 37 and 38 of* Report of the International Commission on Radiological Units and Measurements (ICRU) 1956, *published as National Bureau of Standards Handbook 62, available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., price 40 cents. See also* Meetings on radiation units and protection, *NBS Tech. News Bul.* **40,** *102 (July 1956).*

[2] *Inquiries concerning use of the transfer standard should be addressed to Dr. H. O. Wyckoff, Radiation Physics Laboratory, National Bureau of Standards, Washington 25, D. C.*

A Clamp-Type A-C Microammeter

A PORTABLE, battery-powered, transistorized microammeter developed at the Bureau provides a rapid, convenient method for measuring small alternating currents. Since the current pickup is a miniature split-core transformer that can be clamped onto a wire, it is unnecessary to open the circuit to make the measurement. Lowest range of the prototype instrument is 200 μa full scale, and on higher ranges it can accurately determine currents as large as 200 ma. Its frequency range is 50 cps to 100 kc. Instruments embodying the same principles can be used for materially lower and for very much higher ranges. The development was carried out as part of the work in basic instrumentation, a cooperative program sponsored by the Department of Defense, the Atomic Energy Commission, and NBS, and was conducted by G. F. Montgomery and C. Stansbury of the Bureau's electronic instrumentation laboratory.



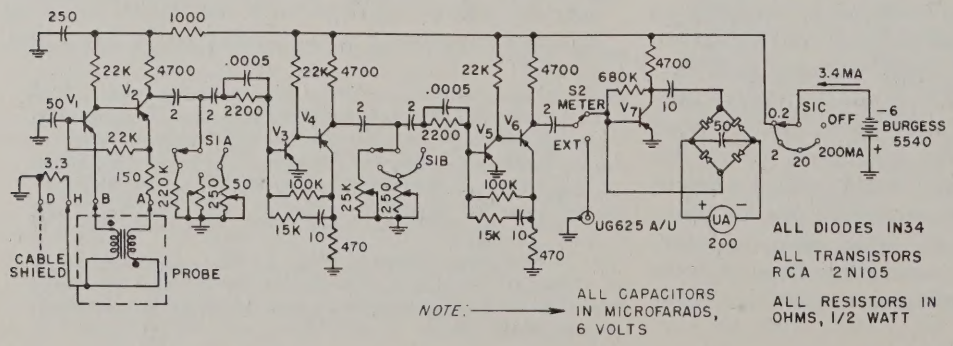
Closeup view of clamp-type probe. Also shown is the core, made up of [- and I-shaped laminations without windings.

For many years, it has been common practice to extend the range of current-indicating instruments by using current transformers. For convenience, the transformer often consists of a secondary winding on a split core that can be clamped around the conductor carrying the current to be measured. This technique suggested a similar device for measuring small currents at audio- and radiofrequencies: an instrument consisting of a small clamp-type magnetic probe and a suitable means for amplifying the probe output to operate an indicating meter. Such an instrument would be complementary to the vacuum-tube voltmeter found in all experimental electronic laboratories. The Bureau's device is not only based on the probe-amplifier-meter concept but is transistorized as well for long life and modest power requirements.

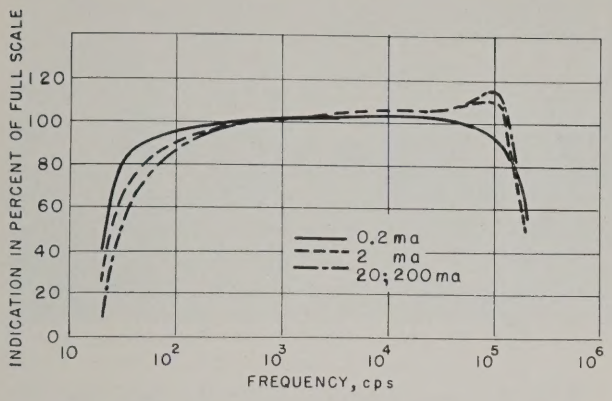
Transformer Design

The core of the transformer consists of 0.014-in. silicon-steel laminations. It is formed of matching [- and I-shaped sections; the I's close the gap of the ['s when assembled. The completed core is $\frac{5}{16}$-in. square, $\frac{1}{8}$-in. thick, and contains a $\frac{1}{8}$-in. window. The core is mounted in a spring-loaded Bakelite clamp, about the size and shape of an ordinary clothespin. The legs of the [project upward from the lower jaw of the clamp, while the I is contained in the upper jaw. A pin passes through the center of the I, providing rotary movement in the plane of the jaws, so that the I will seat itself properly on the projecting legs of the [as the clamp closes. The matching faces of these parts are ground. Shielding with mu-metal minimizes sensitivity to external magnetic fields.

The core [contains two windings, each having 250 turns of number 44 enameled wire. The four coil leads connect to a shielded four-wire cable and plug. One of the windings on the core is considered the secondary, and provides the actual current pickup. The other winding, the tertiary, is part of a feedback network to provide frequency equalization. By using this tertiary winding, transformer output for a particular primary current is very nearly linearized over the frequency range from 100 cps to 100 kc. The primary of the transformer is, of course, the conductor carrying the current to be measured.



Schematic diagram of microammeter.



Graph showing response of microammeter over a wide frequency range.

Circuit Design

Output of the transformer is fed into a preamplifier consisting of two transistors and a feedback network. Gain in this stage is sacrificed to provide frequency equalization and to reduce phase shift at the higher frequencies.

Gain is provided by two intermediate stages, each using a pair of transistors. Each stage uses direct coupling from the first transistor to the next. A feedback network, from the emitter of the second transistor to the base input of the first, stabilizes the d-c operating point for each pair and reduces the over-all current gain of each state to about 20. The a-c feedback factor at low frequency for each stage is about 100; the low-frequency current gain is thus stabilized against transistor and battery aging, and the frequency range for constant response is extended beyond that available without feedback.

The indicating meter has a 200-μa d-c movement and was chosen as a compromise between cost, sensitivity, and ruggedness. The meter is driven through a full-wave rectifier. Although the input current from the intermediate amplifying stages is more than adequate to drive the movement to full scale, it is small compared to the normal operating characteristics of the rectifier. The rectifier, therefore, is operating in a nonlinear region. However, the nonlinearity is effectively reduced by a one-transistor amplifier whose gain is sacrificed to provide negative feedback through the rectifier. Linearity of response of the entire instrument is within the 2-percent specification of the indicating meter itself, and shows that the degree of feedback in the meter network is adequate.

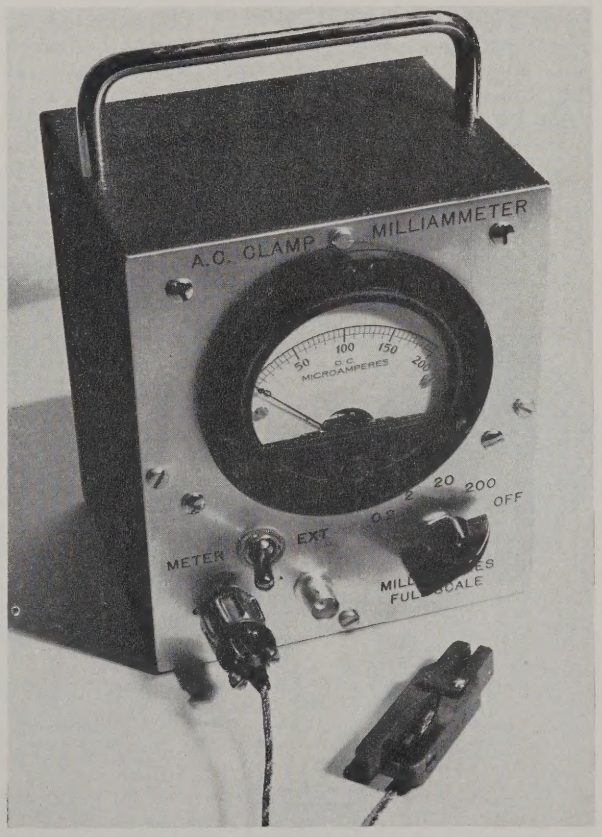
Performance

Whenever current is measured with any type of instrument, an impedance is in effect inserted in series with the circuit carrying the measured current. For the Bureau's microammeter, the insertion impedance is almost entirely resistive over the useful frequency range. This impedance is made up of a resistance of 2.8×10^{-5} ohm and inductance of 2.2×10^{-7} henry in parallel.

In the experimental instrument, the high-frequency limit is imposed mainly by limitations of the transistors used, although even with high-frequency transistors the maximum operating frequency is probably not more than three or four times the transformer resonant frequency of 120 kc. Instruments designed particularly for high-frequency use would probably make use of more appropriate core material and a construction minimizing distributed capacitance.

Another possible application of the general technique used in this instrument is with current transformers for high-voltage power lines, using single through-type primary conductors. However, this application has not been investigated.

[1] *G. F. Montgomery and C. Stansbury,* The clamp-type alternating-current microammeter, *Am. Inst. Elec. Engrs. (33 West 39th St., New York 18, N. Y.) paper No. 57–114 (1957).*



An a-c microammeter with clamp-type probe in foreground.

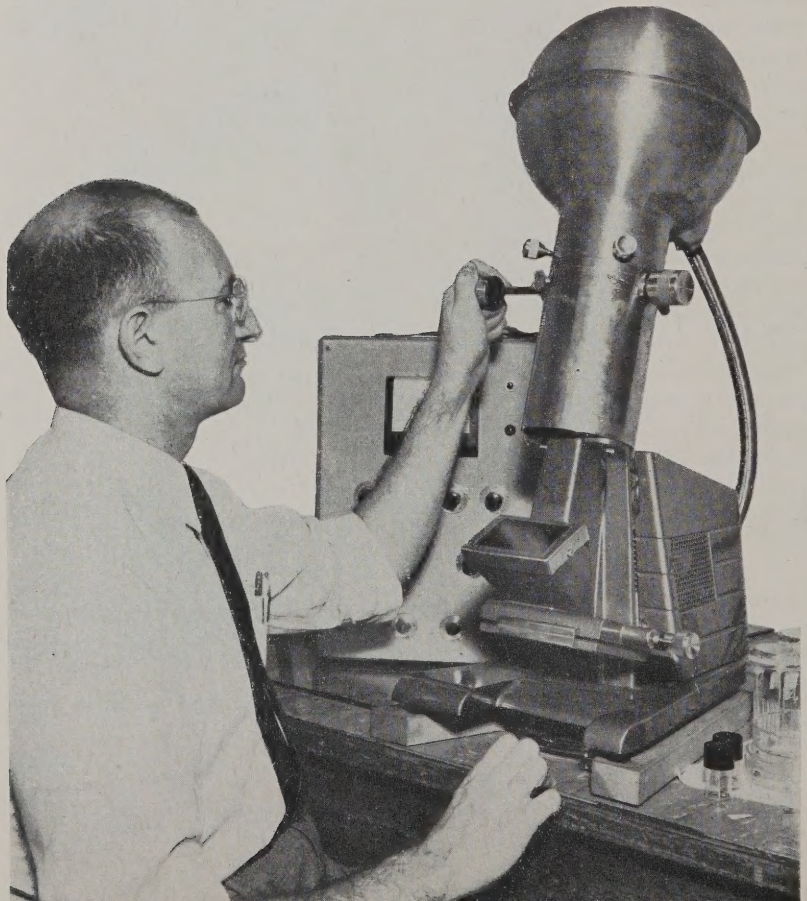
MICROSTRUCTURE OF CRAZED PLASTICS

WHEN a transparent plastic material crazes, that is, forms minute cracks after being molded or cast into shape, its optical and strength properties deteriorate. During the past several years research on multiaxial stretching [1] has vastly improved the finished material; however, a tendency to craze is still encountered in plastic products ranging from aircraft canopies to watch crystals.

In an effort to ascertain the characteristics and mechanism of the crazing phenomenon, an optical study of plastics exposed to stress, or to stress and solvent combined, was undertaken at the National Bureau of Standards. Sponsored by the National Advisory Committee for Aeronautics, the work was conducted by Sanford B. Newman and Irvin Wolock of the Bureau's plastics laboratory.[2] The experimental results may lead to the development of better materials, or to improved methods of handling those now available.

With the multiple-beam interference microscope the investigators found that each surface crack in a crazed specimen is surrounded by a raised area which appears to increase with the size of the crack. Interference fringes, from beams reflected by both the plastic and optical reference surfaces, were observed at the microscope eyepiece. When an undamaged plastic surface was used, the fringes were relatively parallel and showed no abrupt discontinuities. But after the plastic surface had been crazed, peaks appeared in the fringes, indicating abrupt surface discontinuities at each crack.

The parallel fringes mark changes of one-half the wavelength of light in the distance between the specimen and the optical reference surface. Thus the magnitude of any local deviation from flatness can be assessed by the displacement of the fringes appearing in the interferogram. The multiple-beam interference microscope yields large magnifications in the direction of height or depth.



Electron microscope used to study the microstructure of plastics. The surface replica of a plastic specimen, mounted on a piece of 200-wire mesh ⅛ in. in diameter, is being inserted into the microscope's column. When the replica is in place, its enlarged image may be viewed through the rectangular glass port at the front of the microscope.

Results of one experiment showed that a surface crazed by a solvent developed peaks which in some cases extended the total distance between adjacent fringes. Thus, the craze cracks in this field were surrounded by areas dislocated from the remainder of the field by up to 273 mμ, the distance between fringes. The effectiveness of treating plastics to eliminate defects can be calculated from these surface dislocations.

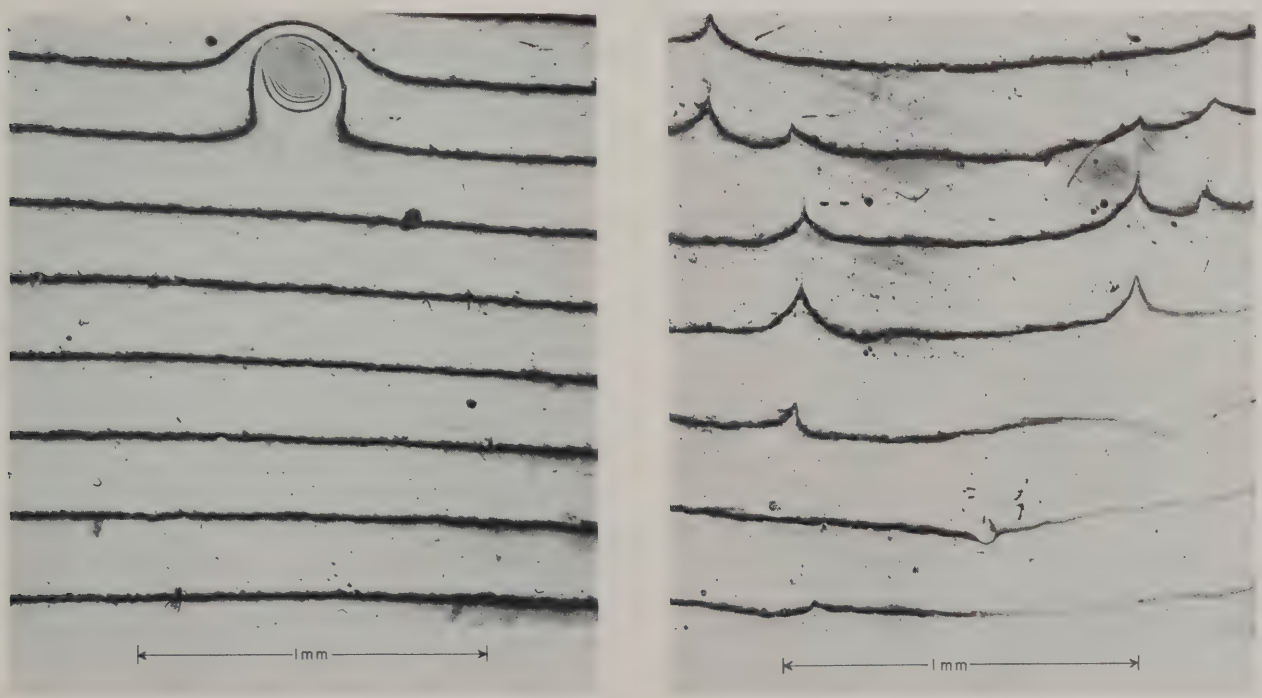
It has been shown in the past that when a crazed plastic object is heated at elevated temperatures, clarity is restored to the object. In the present investigation, specimens of polymethyl methacrylate were stress-solvent-crazed and then heated in an air-circulating oven for periods up to 15 hours. Upon examination with either the bright field microscope or the unaided eye, the heat-treated specimens appeared clear and uncrazed. However, multiple-beam interferometry of their surfaces revealed dislocations similar to those found on unheated stress-solvent-crazed specimens.

Sufficient flow had occurred in the heated specimens to close the cracks but not to eliminate the large mass of dislocated material around the crack. The sites of the original failures would, no doubt, produce cracks again when exposed to stress. From this it is obvious that treating stress-solvent-crazed structures with heat does not restore the material to its pristine state. Acrylic sheets crazed by stress alone appear to recover more completely; however, residual surface dislocations would be expected from the known rheological properties of the plastic.

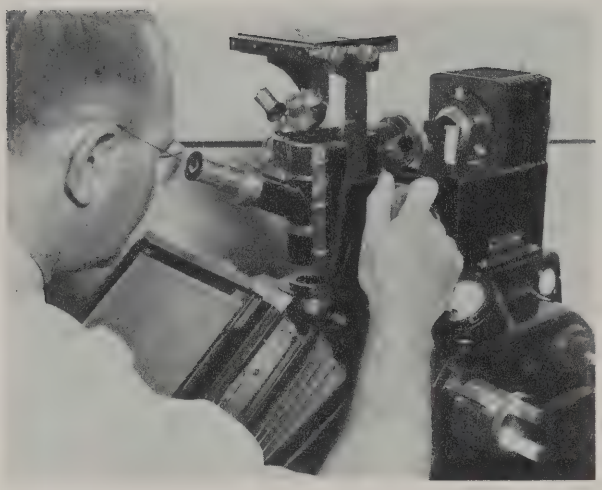
Crazing in polymethyl methacrylate is a purely surface phenomenon; that is, all of the observed cracks intersect the surface plane. But both surface and internal cracks were observed in the other two plastics investigated, polystyrene and polymethyl alpha-chloroacrylate. Whether the distribution of craze cracks in these plastics is an intrinsic characteristic or is due to the level of refinement of the manufacturing process could not be ascertained. In the polystyrene specimens investigated, the internal cracks were usually associated with foreign particles or other inhomogeneities in the matrix.

Optical studies reveal another method of stress relaxation in plastic surfaces. When acrylic specimens break at strains of approximately 20 percent, they first craze and then develop a series of flow lines. As their name implies, flow lines are part of the unrecoverable stress response. The flow lines form an angle of from 35° to 45° with the long dimension of the craze cracks. Multiple-beam interference techniques indicate that the traces of these flow lines are superficial, not rising more than 25 to 50 mμ above the surface. In some acrylic specimens the flow lines were observed although the craze cracks had disappeared after a long recovery period.

Residual adhesive from the masking paper applied to protect the surface of plastic sheets may cause deterioration. Flow lines were found to radiate from nuclei consisting of droplets of adhesive after specimens had been subjected to high stresses. Furthermore, the



Left: **Multiple-beam interferogram of an uncrazed surface of cast polymethyl methacrylate. Some fine detail may be observed along the fringes. Body deformations appear to exert a measurable effect on the over-all fringe pattern. The rounded detail at the top of the photograph is typical, and apparently due to residual adhesive from masking paper.** ***Right:*** **Multiple-beam interferogram of a stress-solvent-crazed surface of polymethyl methacrylate. The sharp discontinuities in the fringes mark the loci of the craze cracks.**



Scientist focusing microscope used for multiple-beam interferometry. The housing to the rear contains a high-pressure mercury lamp. Light from the lamp passes through filters in front of the housing to a beam splitter that diverts the light into the interferometer above the view's hand. The light produces fringes in the interferometer which are viewed through the ocular, and are photographed on the ground glass plate below the ocular. Note the multiple-beam interferometer which consists of a metal-coated plastic specimen resting on a metalized glass optical reference surface.

craze cracks were found to gape more widely and to occur in larger numbers where traces of adhesive had remained on the surface. It is possible that the effect of the adhesive increases the longer it remains in contact with the material.

A limited number of electron microscope observations were made on surface replicas of crazed acrylic specimens. The replicas were prepared according to a method described by Zworykin and Ramberg.[3] As electron microscopy limits the size of the specimen, only surfaces containing fine cracks were examined.

Dimensions of the finest cracks were measured with fair precision. Lengths varied from 2 to 10 μ; widths from 0.10 to 0.25 μ; depths from 0.05 to 0.15 μ. Because the dimensions of all observed cracks could be resolved in the electron microscope, it is concluded that plastics have a minimum craze-crack length. Possibly, a specific minimum amount of energy is required to separate the chain segments of a plastic material and, as such separation leads to crazing, the energy threshold results in a minimum crack size. Further investigations will be made to determine exactly the minimum crack size of different plastics under varying conditions.

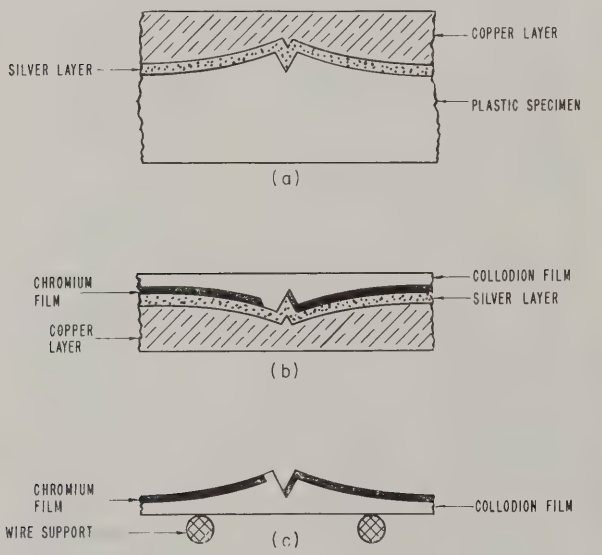
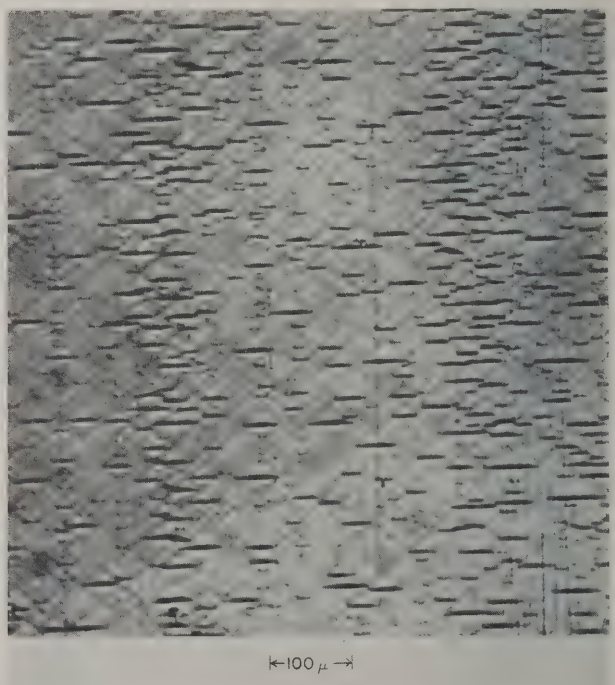


Diagram of method followed by the Bureau in preparing electron microscope specimens. (a) Silver is vacuum-deposited on the plastic sheet. A thicker layer of copper is then electrodeposited on the silver. (b) The silver-copper layer is stripped from the plastic and shadowed with chromium. Collodion is then flowed over the chromium, forming a film replica. (c) Silver and copper films are removed with acid and the chromium shadow is mounted on a supporting grid.

[1] Development of craze and impact resistance in glazing plastics by multiaxial stretching, *by G. M. Kline, I. Wolock, B. M. Axilrod, M. A. Sherman, D. A. George, and V. Cohen, NACA Report 1290 (1956).*

[2] *For further technical details, see* Optical studies of crazed plastic surfaces, *by Sanford B. Newman and Irvin Wolock, J. Research NBS* **58,** *339 (1957) RP2767.*

[3] Surface studies with the electron microscope, *by V. K. Zworykin and E. G. Ramberg, J. Appl. Phys.* **12,** *692 (1941).*



Surface of a stress-crazed tensile specimen of polymethyl methacrylate. The image has been slightly defocused to emphasize the diagonal flow lines at the ends of the cracks.

Helium Liquefaction With the Large Hydrogen Liquefier

A RECENT EXPERIMENTAL RUN at the Boulder Laboratories has shown that one of the Bureau's large hydrogen liquefiers [1] can be slightly modified to liquefy helium in large quantities.

Carried on under the direction of Victor J. Johnson of the Cryogenic Engineering Laboratory, the test resulted in about 125 liters of liquid helium being collected in the liquefier in slightly more than 1 hour of liquefaction with the plant operating at two-thirds capacity. The liquefaction rate for the test apparently averaged about 120 liters per hour.

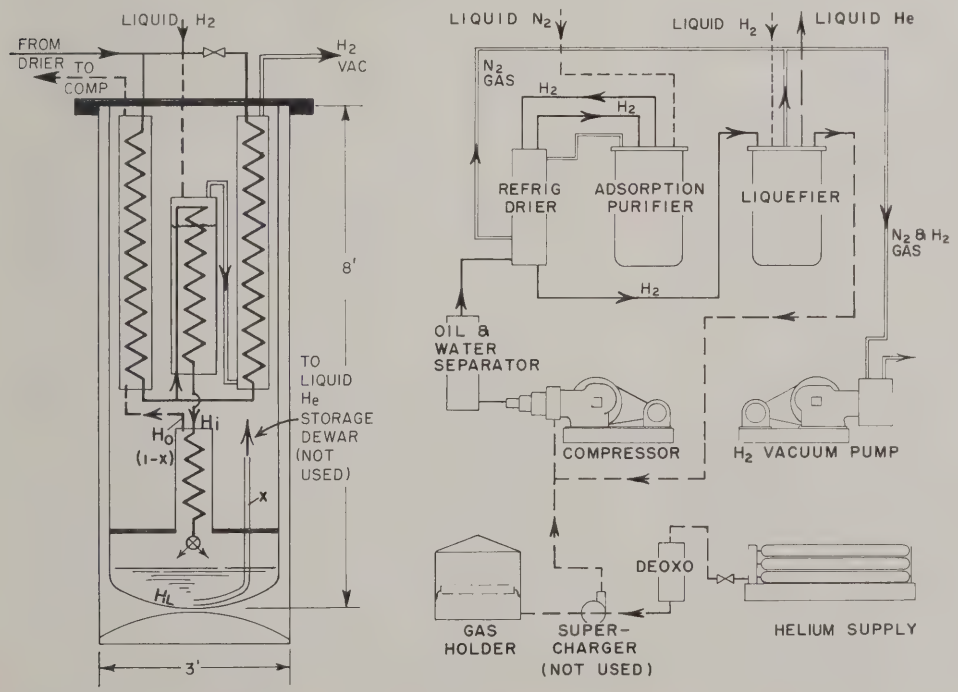
When operating at full capacity at Boulder conditions (4/5 of an atmosphere ambient pressure due to 5,400 feet altitude), the plant can liquefy about 320 liters of normal liquid hydrogen per hour. The simple Joule-Thomson liquefaction process is used with precooling supplied from liquid nitrogen boiling at about 65° K. To modify the liquefier for liquefaction of helium instead of hydrogen, the liquid hydrogen transfer line from the bottom of the liquefier to the storage Dewar was removed from the bottom of the liquefier and reconnected to the precooling chamber. Suitable precautions were taken regarding insulation of the line to prevent undesirable temperature gradients and improper heat transfer in the liquefier. No changes were made in the control instruments, valves, or heat exchangers except to note changes in instrument calibration for liquid and gaseous helium.

The liquefier was cooled to about 75° K by circulating gaseous helium precooled with liquid nitrogen. The liquid nitrogen supply was then shut off, and as soon as that remaining in the liquefier had evaporated, liquid hydrogen was admitted to the precooling bath. It took about an hour to finish cooling the liquefier to the point that liquid helium started to collect. A little more than 200 liters of liquid hydrogen were required. During the liquefaction period about 1.5 liters of liquid hydrogen were required as a precoolant for each liter of liquid helium collected. Thus about 190 liters was used to liquefy the 125 liters collected.

The actual liquefaction yield (fraction liquefied) was about 12.1 percent. Two compressors were used, each with 250 cfm at intake conditions (12.8 psi at 70° F). The total gas circulated was 4.55 lb/min, which is equivalent to 990 liters per hour of liquid helium. The fraction liquefied then was 120/990, or 12.1 percent.

This test demonstrated that the large liquefier can be used for producing large quantities of liquid helium. With the use of three compressors, improved instrumentation, and control, it is expected that a yield of 200 liters per hour could be approached.

[1] *NBS Tech. News Bul.* **37**, *152 (Oct. 1953).*



Left: **Schematic layout of the hydrogen liquefier showing arrangement of heat exchangers and the precooling bath as connected to a liquid hydrogen fill line instead of the liquid nitrogen fill line which is used normally for liquefaction of hydrogen.** ***Right:*** **Flow diagram of the liquefier system showing arrangement of major plant components. In converting to liquefaction of helium instead of hydrogen, liquid hydrogen is added to the liquefier for precooling compressed helium gas, and gaseous helium is supplied to the system instead of gaseous hydrogen.**

Modification of the Basis for Roentgen Calibrations Between 0.5 and 3 Mev

IN A JOINT STATEMENT (given below), the National Bureau of Standards in Washington, D. C., and the National Research Council of Canada have announced a change, to take effect January 1, 1958, in the basis for instrument calibrations in roentgens in the energy region from 0.5 to 3 Mev. The change is due to a revised estimate, based on improved data, of the "stopping-power" corrections that must be applied to the materials involved in the calibration.

Affecting instruments that measure radiation exposure dose, the new calibration base results in a small change in the calibration factor for radiation in the indicated higher-energy range. Thus, to conform to the new basis, instruments calibrated in roentgens with cobalt-60 gamma rays prior to January 1, 1958, should have their calibration factors reduced by 1.8 percent; and those whose scales were calibrated prior to that date should have their scale readings changed in the same way— i. e., multiplied by 0.982.

Radiation exposure dose is a measure of the radiation incident at a point in terms of its ability to produce ions in air. For radiation energies below 0.5 Mev, a relatively direct measurement of the amount of such ionization can be made with the free-air ionization chamber. At higher energies, however, the size of the chamber required becomes impracticably large, even when the air density is increased by maintaining a high pressure.

Hence, at higher energies a different instrument is used, consisting of a small air cavity surrounded by a wall of solid material several millimeters thick. The ionization produced within such a cavity is caused mainly by electrons that the radiation ejects from atoms in the wall. As a result, in calibrating such a device, the most important parameter is the ratio of the stopping power (roughly, ability to absorb radiation energy) of the wall material to that of air. Alternatively, cavity instruments are sometimes calibrated with the radiation from a known weight of radium in a platinum capsule, and this requires a knowledge of the exposure dose rate at 1 cm from such a source. However, this rate has been determined from cavity-chamber measurements. Thus all measurements of exposure dose in the 0.5- to 3-Mev region depend on values for the stopping power.

As indicated in the joint statement that follows, recent experimental studies of stopping power gave results that disagree somewhat with the values calculated by the method hitherto in use. The revised calibration base was adopted after careful analysis of these laboratory studies, which were carried out by the National Research Council (Canada), the National Bureau of Standards, and others.

Joint Statement

As a result of recently accumulated information the National Bureau of Standards (U. S.) and the National Research Council (Canada) have decided to change the base for instrument calibrations in roentgens in the energy region from 0.5 to 3 Mev. This note announces the date the change will become effective and the reasons for it.

Only a few measurements with free-air chambers have been attempted in the megavolt region, and there seems to be some doubt as to the adequacy of all of these measurements. Most roentgen measurements in this region are actually made with cavity ionization chambers. Their sensitivity is determined either from the Bragg-Gray relation with a stopping-power correction, or from the calibration of a chamber with radium together with a value for the number of roentgens per hour at 1 cm from 1 mg of radium encapsulated in 0.5 mm of platinum. Because the value of this constant (k) is determined from cavity-chamber measurements, it is evident that all measurements in roentgens in the megavolt region depend upon a stopping-power correction at the present time.

Until now the stopping-power corrections used by the National Bureau of Standards and the National Research Council have depended on the analysis of Laurence,[1] which was based on a theoretical assumption of the dependence of stopping power on atomic number. When this analysis was applied to the experimental determinations of k, the mean value obtained was close to 8.4 r/hr at 1 cm from 1 mg of radium encapsulated in 0.5 mm of platinum. This value has been widely used. However, subsequent measurements of stopping powers by Bakker and Segré[2] give a somewhat different dependence on atomic number. Furthermore, independent measurements recently made at the National Research Council[3] and the National Bureau of Standards[4] of the ionization produced within cavity chambers having different wall materials are more nearly consistent with the values of Bakker and Segré than with those used by Laurence. Attix and Ritz[4] have made a careful redetermination of k; using stopping-power corrections based on the values of Bakker and Segré, a stopping power for air based upon a mean excitation potential of 80.5 ev, and including a correction for the difference in the "density effect" between the cavity wall and the gas based on the calculations of Sternheimer;[5] their value is $k=8.26\pm0.05$. Henry[6] has recently obtained the value 8.24 ± 0.08. Finally, a re-evaluation by Whyte[7] of a number of measurements appearing in the literature gives a mean value of 8.22.

The evidence indicates the desirability of modifying the calibration basis for megavolt radiation. Therefore, after January 1, 1958, calibrations in the energy region from 0.5 to 3 Mev at the National Bureau of Standards and the National Research Council will be based on the Bakker and Segré stopping-power values, an average excitation potential of 80.5 ev for air, and the Sternheimer density correction. The value $k=8.25$ r/hr at 1 cm from 1 mg of radium encapsulated in 0.5 mm of platinum will be used instead of 8.4. For all instruments that were calibrated in roentgens with cobalt-60 gamma rays prior to this date, the calibration factor should be reduced by 1.8 percent in order to agree with the new value (i. e., the calibration factor should be multiplied by 0.982).

[1] The measurement of extra-hard X-rays and gamma-rays in roentgens, *by G. C. Laurence, Can. J. Research* **A15,** *67 (1937).*

[2] Stopping power and energy loss for ion pair production for 340 Mev protons, *by C. J. Bakker and E. Segré, Phys. Rev.* **81,** *489 (1951).*

[3] Measurement of the Bragg-Gray stopping-power correction, *by G. N. Whyte, Radiation Research* **6,** *371 (1957).*

[4] A determination of the gamma-ray emission of radium, *by F. H. Attix and V. H. Ritz, J. Research NBS* **59,** *293 (1957) RP2801.*

[5] The density effect for the ionization loss in various materials, *by R. M. Sternheimer, Phys. Rev.* **88,** *851 (1952).*

[6] *W. H. Henry, private communication (1957).*

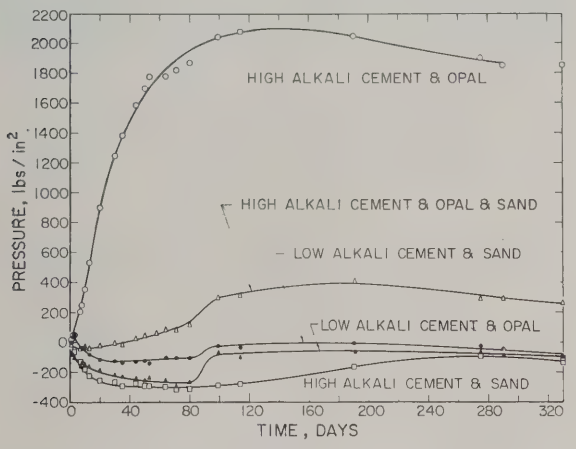
[7] *G. N. Whyte, private communication (1957).*

Destructive Alkali-Aggregate Reaction in Concrete

THE CONTENT of sodium and potassium oxides in portland cement sets an important limitation on its use for many applications. For example, where the cement is to be combined with crushed rock or gravel to make concrete, the alkalies may sometimes react with soluble silica present in the aggregates. This causes expansion of the concrete, resulting in the formation of cracks and weakening of the structure.

Although methods have been developed to partially control this destructive alkali-aggregate reaction, the basic causes and mechanisms of the reaction are not fully understood. R. G. Pike and D. Hubbard of the Bureau have recently completed an extensive investigation of the alkali-aggregate reaction. Besides measuring the pressure developed in the reaction, the study also considered the role of the physicochemical properties of the aggregates in concrete disintegration.

To measure the pressure developed by the alkali-aggregate reaction, the Bureau fabricated a special cell from a solid piece of cold rolled steel.[1] The sensitive element is an electrical resistance-type strain gage cemented spirally to the outside of the cell. The first



Graphical results of pressure readings for various combinations of cement and aggregate over a period of 330 days. Pressures above the tensile strength of concrete are developed in the high alkali cement and opal combination.

step in measuring the pressure is to calibrate the cell against known hydrostatic pressures. It is then filled with a mixture of portland cement and reactive aggregate, and sealed so that no moisture can be lost or gained. The initial pressure reading is recorded as zero. Increase or decrease in pressure is then read on the strain indicator every few hours at the start of the test and later at intervals of several days.

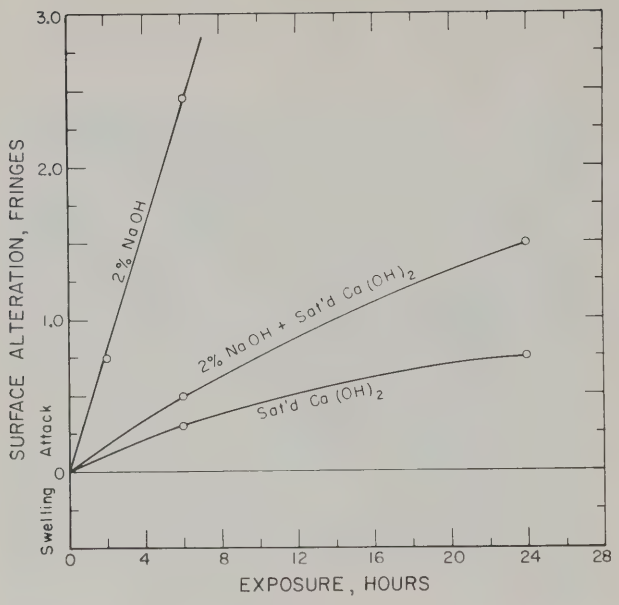
Readings over a period of several months indicate pressures above 2,000 lb/in.², which is greatly in excess of the tensile strength of concrete. This increase of pressure due to expansion is attributed to the alkali-aggregate reaction and is often responsible for the

Cell and strain gage designed to measure destructive pressures developed by the alkali-aggregate reaction in cement pastes and mortars. The resistance wire strain gage is wrapped spirally around the cement-filled cell (left) and connected to a strain indicator. As the cement mixture expands the strain gage wire changes its resistance and this change is indicated on the central scale (directly above hand) of the indicator. Between the cell and the indicator is a compensator of the same design as the cell. When the cell is empty the strain gage and compensating gage give a zero reading. Later readings are the difference between the stationary pressure of the compensator and the pressure developed in the cell.

cracking and disintegration of concrete. An investigation of the factors that cause the expansion was therefore undertaken.

In studying the reaction mechanism the Bureau found that alkalies alter several of the physicochemical properties of aggregates.[2] Alkalies may either attack the surface of the aggregates or cause appreciable swelling. The chemical durability or surface alteration of the aggregates was investigated by an interferometric method. Half of a specimen with a flat polished surface was immersed in an alkaline solution. The unexposed portion of this sample was then used as the reference plane for interferometric measurements. The interference fringes produced by the interferometer were displaced at the boundry between exposed and unexposed portions of the sample. By determining the displacement of these fringes, the chemical attack on the exposed surface was measured.

There has been considerable discussion of the role of calcium hydroxide in this reaction with evidence indicating that it is both necessary for the reaction to proceed and conversely that it inhibits the reaction. The interferometric procedure used at the Bureau appears to show that calcium hydroxide can have an inhibiting effect on this reaction. Similar interfer-



Graphical results of interferometric tests of surface alterations. Sodium hydroxide solution rapidly attacks a synthetic aggregate (barium crown glass 572). Calcium hydroxide solution is shown to cause a slower attack and to have an inhibiting effect when added to the sodium.

ometric tests also show that certain solutions, including sodium hydroxide, can cause swelling of reactive aggregates, even in the absence of any cement paste membrane.

Investigations on the hygroscopicity of the aggregate materials were conducted to determine the role of water in the alkali-aggregate reaction. Water is not only required for this reaction but is one of the chief constituents of the products resulting from the reaction. The hygroscopicity study involved weighing the aggregate sample, exposing it in a moist atmosphere, and reweighing it. The amount of water absorbed was calculated from the increase in weight. A possible correlation was found between hygroscopicity and destructive expansion in various materials.

The magnitude and polarity of the excess ionic charge on various portland cements were also found to affect expension. The procedure adopted in this determination uses the silver-ammonia-bromide complex as the indicator ion. Potentiometric measurements revealed that aggregates with an excess positive ionic charge (similar to the positive charge on portland cements) cause much less rapid expansion of concrete than do those aggregates with a negative charge.

Using an interferometer to measure the surface alteration of an aggregate which has been partly immersed in an alkaline solution. The extent of the chemical attack was calculated from the shift in the interference pattern caused by the attack on the sample.

[1] Pressures developed in cement pastes and mortars by the alkali-aggregate reaction, *by Robert G. Pike, Bul. Hwy. Research Bd. 171 (in press).*

[2] *For further technical details, see* Physicochemical studies of the destructive alkali-aggregate reaction in concrete, *by Robert G. Pike and Donald Hubbard, J. Research NBS* **59**, *27 (1957) RP2780;* Mechanisms of alkali-aggregate reaction, *by Robert G. Pike, Donald Hubbard, and Herbert Insley, Proc. Am. Concrete Inst.* **52**, *13 (Sept. 1955);* *and* Miscellaneous observations on the alkali-aggregate reaction and the ionic charge on hydrated cement, *by Robert G. Pike and Donald Hubbard, Bul. Hwy. Research Bd. 171 (in press).*

FREE RADICALS SYMPOSIUM

A SYMPOSIUM on the Formation and Stabilization of Free Radicals was held at the Bureau on September 18 to 20, bringing together more than 400 scientists from industrial and university laboratories throughout the United States, England, France, Canada, and Italy. More than 20 papers were presented, devoted primarily to current research on the properties of systems containing trapped atoms and radicals. The meeting was sponsored by the Bureau, the Applied Physics Laboratory of the Johns Hopkins University, the Catholic University of America, and the University of Maryland. Arnold M. Bass, NBS, was chairman of the Symposium Committee.

Although these highly reactive molecular fragments have attracted the attention of scientists since the early part of the nineteenth century, it was not until a few years ago that methods were developed for capturing and storing them. Ordinarily they exist for only a few thousandths of a second, in systems such as flames and hot gases. However, by freezing the products of an electric discharge at a few degrees above absolute zero, for example, it is possible to trap free radicals in a highly excited state, in which they can be kept for hours, and studied by a number of physical and chemical techniques. Other methods for capturing and storing them include irradiation of material with gamma rays, X-rays, or ultraviolet light, and bombardment

with accelerated particles, such as electrons, neutrons, or protons.

The first paper at the Symposium was delivered by Francis Owen Rice, the Catholic University of America, who spoke on the history of free radicals. He described the chain of events that had led scientists through periods in which first, the separate existence of free radicals was theorized, then was gradually abandoned when it was impossible to isolate them, and finally, to the present day, when they are opening up a new field of research for both chemists and physicists.

George Moe, Aerojet-General Corp., presented a talk on the possibilities of using free radicals in connection with rocket fuels. The thrust derived from a rocket is related to the energy content of the propellant. Whereas the maximum specific impulse (impulse per pound) of ordinary chemical propellant systems ranges from 350 to 400 lbf-sec/lbm, the heat of reaction of free radicals in a suitable working fluid might raise the specific impulse above this level, resulting in significant increases in the performance of the rocket propellant.

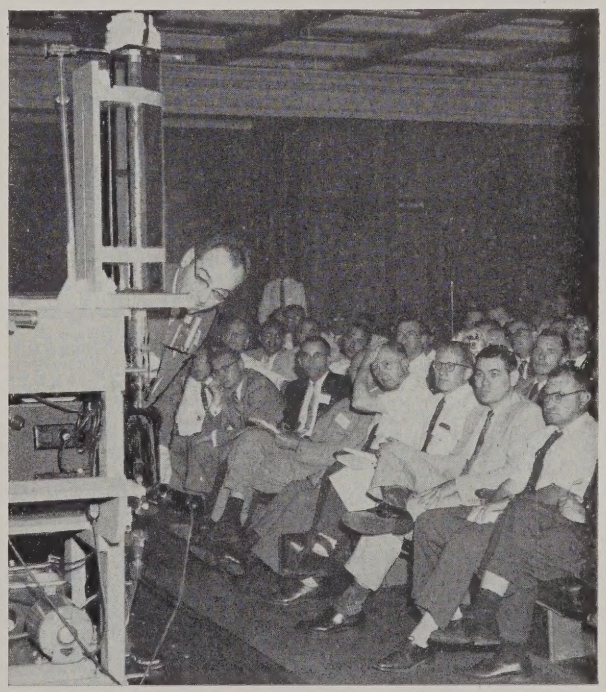
Interest in free radicals was not restricted to the physical sciences. Barry Commoner, the Henry Shaw School of Botany, Washington University, summarized investigations on the occurrence and activity of free radicals in living cells and tissues. Indirect evidence suggests that they may participate in several important biological processes such as chemical carcinogenesis and mutagenesis. He said that the recent development of the electron spin resonance technique has permitted direct investigation of some of these problems.

Bertram Donn, Wayne State University, discussed the role of free radicals in astronomy. He pointed out that at the low temperatures (below 100° K) of interstellar dust and comet nuclei, trapped radicals may be present. Additional observations on comets would not only add valuable data to this hypothesis, but would also check some of the conclusions of the free radical hypothesis. Dr. Donn is currently on loan to the Bureau, participating in its cooperative research program in free radicals.

At a dinner on the evening of September 19, the conferees heard an address by William M. Holaday, Special Assistant to the Secretary of Defense for Guided Missiles. Mr. Holaday told of the interest the Department of Defense has in free radicals, as they may be applied to the field of rockets and missiles. He stressed the role of basic research in technological progress, and suggested that free radicals may someday rank in importance with the development of the atomic bomb in opening new horizons in many fields of science.

On the last day of the conference, Herbert P. Broida, Chief of the Free Radicals Research Section at NBS, discussed the free radicals research program that is being conducted at the Bureau under sponsorship of the Department of the Army. He also performed an experiment in which he demonstrated some of the unusual glows given off by nitrogen atoms condensed in solid form from an electrical discharge.

Other speakers and topics included Free Radical Stabilization in Condensed Phases, delivered by Sidney Golden, Brandeis University and NBS; Experiments on Frozen Free Radicals, by Norman Davidson, California Institute of Technology; Chemical Reactions of Frozen Free Radicals, by Robert A. Ruehrwein, Monsanto Chemical Company and NBS; Atom Recombination Reactions at Low Temperatures, by Gabriel J. Minkoff, Imperial College (London) and NBS; Paramagnetic Resonance of Free Radicals, by George K. Fraenkel, Columbia University; Characteristic Electron-Spin Resonances of Free Radicals Within Solids, by Walter Gordy, Duke University; Studies of Stably Trapped Free Radicals in Solids by Paramagnetic Resonance, by Ralph Livingston, Oak Ridge National Laboratory; The Detection and Identification by Electron Spin Resonance Techniques of Trapped Free Radicals, by Roy S. Anderson, University of Maryland; Paramagnetic Resonance Studies of Organic Free Radicals Produced by Gamma Radiation, by Bernard Smaller, Argonne National Laboratory; Free Radicals Trapped at Liquid Helium Temperature and Their Identification by Electron Spin Resonance, by C. K. Jen, Applied Physics Laboratory, Johns Hopkins University; Free Radical Ions of Hydrocarbons, by Samuel I. Weissman, Washington University; Free Radicals Production by Gamma Radiation, by Leo A. Wall, NBS; Matrix Isolation Method—Some Studies by Electronic Spectroscopy, by Sidney Leach, University of California, Berkeley; The Spectra of Free Radicals in the Gas Phase, by Donald A. Ramsay, National Research Council, Ottawa; Absorption Spectroscopy of Species from Electrical Discharges Condensed at Low Temperatures, by Kenneth B. Harvey, NBS; and Emission Spectroscopy of Nitrogen from Electrical Discharges Condensed at Low Temperatures, by Maurice Peyron, University of Lyon and NBS.



H. P. Broida, of the Bureau staff, demonstrating the green glows provided by atomic nitrogen, to the audience at the Free Radicals Symposium.

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Publications of the National Bureau of Standards

Journal of Research of the National Bureau of Standards, Volume **59**, No. 5, November 1957 (RP2801 to RP2805 incl.), 60 cents. Annual subscription $4.00.

Technical News Bulletin, Volume **41**, No. 11, November 1957. 10 cents. Annual subscription $1.00.

Basic Radio Propagation Predictions for February 1958. Three months in advance. CRPL–D 159. Issued November 1957. 10 cents. Annual subscription $1.00.

Research Papers

Journal of Research, Volume **59**, *No. 5, November 1957. 60 cents.*

RP2801. A determination of the gamma-ray emission of radium. Frank H. Attix and Victor H. Ritz.

RP2802. Radiation from slots on dielectric clad and corrugated cylinders. James R. Wait and Alyce M. Conda.

RP2803. Infrared emission spectrum of methane at 3.3 microns. Earle K. Plyler and Lamdin R. Blaine.

RP2804. Term analysis of the first spectrum of rhenium (Re I). P. F. A. Klinkenberg, W. F. Meggers, R. Velasco, and M. A. Catalán.

RP2805. An apparatus for measurement of thermal conductivity of solids at low temperatures. Robert L. Powell, William M. Rogers, and Don O. Coffin.

Circulars

C539. Volume 7. Standard X-ray diffraction powder patterns. Howard E. Swanson, Nancy T. Gilfrich, and Marlene I. Cook. 40 cents.

Handbooks

H28. Part I. Screw-thread standards for federal services (1957). $1.25.

Publications in Other Journals

Field-strength variations recorded on a VHF ionospheric scatter circuit during the solar event of February 23, 1956. Hope I. Leighton. J. Geophys. Research (Editorial Office, 5241 Broad Branch Rd., N. W., Washington 15, D. C.) **62** (1957).

Further studies of an electronic thickness gage: circuitry, operating characteristics, and calibration. Frederick P. Brodell and Abner Brenner. Plating. (The American Electroplaters' Society, American Bldg., 445 Broad St., Newark 2, N. J.) **44**, No. 6, 591–601 (June 1957).

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NBS Publications (*continued*)

A method for measuring surface flammability of materials using a radiant energy source. A. F. Robertson, D. Gross, and J. Loftus. Am. Soc. Testing Materials. (American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.) **56,** 1437–1453 (1956).

Oxygen and water vapor absorption of radio waves in the atmosphere. B. R. Bean and R. Abbott. Geofis. pura e appl. (Instituto geofisico italiano, Piazza Lenoardo da Vinci 12, Casella Postale 3689, Milan, Italy) **37,** 127–144 (1957).

On the mode theory of V.L.F. ionospheric propagation. J. R. Wait. Geofis. pura e appl. (Instituto geofisico italiano Piazza Leonardo da Vinci 12, Casella Postale 3689, Milan, Italy) **37,** 103–105 (1957).

Pairs of matrices of order two which generate free groups. K. Goldberg and M. Newman. Illinois J. Math. (Dept. of Math., University of Illinois, Urbana, Illinois) **1,** No. 3, 446–448 (Sept. 1957).

The structure of bone mineral. Aaron S. Posner. Clinical Orthopaedics. (J. B. Lippincott Co., Philadelphia, Pa.) No. 9 (1957).

The strontium oxide content of portland cements. Leonard Bean. ASTM Bull. (American Society for Testing Materials, Philadelphia 3, Pa.) No. 224 (Sept. 1957).

Survey of hazards of handling liquid oxygen. C. S. McCamy. Ind. Eng. Chem. (American Chemical Society, 1155 16th St., N. W., Washington 6, D. C.) **49,** 81A (Sept. 1957).

Techniques and theory of fast coincidence experiments. Zoltan Bay. I.R.E. Trans. on Nuclear Sci. (The Institute of Radio Engineers, 1 E. 79th St., New York 21, N. Y.) **NS3,** No. 4. 12 (1956).

Molecules in the solar spectrum. Herbert P. Broida and Charlotte E. Moore. Mem. soc. roy. sci. Liège. (Societe royale des sciences de Liège, Univ. de Liège, Place du XX Aout 7, Liège, Belgium) **18,** 217–230 (1957).

Rotational lines of CH, OH, and CN in the solar spectrum. Charlotte E. Moore and Herbert P. Broida. Mem. soc. roy. sci. Liège. (Societe royale des sciences de Liège, Univ. de Liège, Place du XX Aout 7, Liège, Belgium) **18,** 252–263 (1957).

Medida del color en la industria. Deane B. Judd. Bol. Iberoamericano de cultura technica. (Departmento de Informacion y Publicaciones de la Oficina de Educacion Iberamericana, Avda. de los Reyes Catolicos, Ciudad Universitaria, Madrid, Spain) **1,** No. 1, 13–30 (July–Sept. 1957).

Publications for which a price is indicated are available only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. (foreign postage, one-fourth additional). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

Patents

(The following U. S. Patents have been granted to NBS inventors. Assigned to the United States of America, as represented by the Secretary of the Department noted in parentheses.)

No. 2,798,207. July 2, 1957. Magnetic microwave attenuators. Frank Reggia (Commerce).

No. 2,798,958. July 9, 1957. Apparatus for producing radiographs of selected structures within a subject. Donald C. Hudson and John W. Kumpula (Army).

No. 2,802,390. August 13, 1957. Smoke colorimeter. Isadore Nimeroff and Samuel W. Wilson (Army).

No. 2,804,606. August 27, 1957. Pulse height analyzer system. John H. Reaves (Commerce).

No. 2,804,613. August 27, 1957. Ship centered P. P. I. Leland J. Haworth (Navy).

No. 2,805,357. September 3, 1957. Obturator probe for control of carbon arc lights. David A. Walsh, Theodore H. Projector, and William F. Mullis (Navy).

No. 2,805,394. September 3, 1957. Alternating-current voltammeters. Francis L. Hermach (Commerce).

No. 2,805,898. September 10, 1957. Fluid current conveyor for fragile articles. Edward A. Willis, Jr. (Navy).

No. 2,806,155. September 10, 1957. Piezoelectric crystal traveling-wave transducer. Israel Rotkin (Commerce).

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